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MICROCOPY RESOLUTION TEST CHART

Report Number 70

VOLUNTARY SELF-CONTROL OF SLEEP
TO FACILITATE QUASI-CONTINUOUS PERFORMANCE

Annual Summary Report

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For the period 1 April 1977 to 30 June 1978)

ABSTRACT

The aim of our research has been to evaluate the potential of napping for facilitating quasi-continuous functioning. Earlier work by this laboratory has isolated individual napping patterns. Replacement nappers are individuals who utilize naps to make up for lost sleep or in anticipation of future sleep loss. Appetitive nappers nap even in the absence of fatigue because they enjoy the experience and derive psychological benefit from the nap. Non-nappers neither nap, nor do they find naps helpful. The current study expands these findings and explores the effect of asking individuals to nap in an environment not conducive to sleep. Further, it examines the effect of naps on performance. The overall thrust is to develop the concept of prophylactic napping as a means of training soldiers to utilize available slack time during quasi-continuous performance to prevent the accumulation of sleep debt, and thus maintain optimal functioning. In this report an updated review of the relevant literature on napping and fragmented sleep is included. Studies are discussed in relation to our approach to the use of napping. Further findings relevant to these issues are presented, including differences in sleep efficiency, delta sleep onset, oral temperature, and the factors that influence the ease of napping.

ACKNOWLEDGMENTS

FOREWORD

In conducting the research described in this report
the investigators adhered to the Institutional Guide to DHEW
Policy on Protection of Human Subjects as outlined by the
National Institute of Mental Health. The Research Review
Committee of the Pennsylvania Hospital evaluates the proto-
cols of studies being conducted, the type of subjects,
method of recruitment, screening process, as well as the
risks, voluntary participation and the manner in which in-
formed consent is obtained. The procedures were most
recently reviewed and approved on March 29, 1978.

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BACKGROUND

The need to sleep, much like the need to eat, can become a prepotent force in the lives of higher animals, including man. On the average, a third of our lives is spent fulfilling a recurrent urge to sleep in order to recover from the day's fatigue. Simply resting each day without actually sleeping does not provide that sense of satisfaction we typically feel after a normal night's sleep, nor will it forestall the growing need to sleep after even short periods of sleep deprivation (Kleitman, 1963; Webb & Agnew, 1974; Lubin, Hord, Tracey, & Johnson, 1976).

Despite the ubiquitous nature of sleep, and the apparently obvious relationship between sleep and recovery from fatigue, the precise physiological benefits that result from sleep remain obscure. Although hundreds of total, partial, and selective sleep deprivation experiments carried out in the past 20 years have documented the dynamic psychophysiological nature of sleep, its multiphasic structure, and the need for specific sleep stages, little insight has been gained into the association between sleep and recovery from fatigue.

Nevertheless, sleep loss does disrupt effective functioning of the individual. Studies of performance, psychological stability, and neurological integrity following sleep deprivation have shown debilitating effects after prolonged periods of wakefulness. The effects are not, however, as obvious as one might expect. Whereas prolonged sleep loss clearly results in increased irritability, lapses of attention,

increased sensitivity to pain, and eventually fine hand tremor, diplopia, and drooping eyelids, it does not produce performance decrements on short, well-learned, interesting tasks, nor does it inevitably result in either profound psychopathology or gross neurological impairment. Further, highly motivated individuals are capable of maintaining relatively good levels of performance for some time, but their functioning on boring, complex tasks requiring continuous attention inevitably shows progressively greater decrements (Naitoh, 1969; Johnson & Naitoh, 1974).

One consistent result in all deprivation studies, however, is that individuals experience ever increasing fatigue -- at least for the first five days of sleep loss. Thus, after a review of the complex and voluminous sleep deprivation literature, it is difficult to avoid the conclusion that sleep loss is manifested most clearly by the overwhelming feeling of fatigue long before decrements in performance or in physiological and neurological functioning can be objectively documented. In a recent comprehensive study of progressive shortening of nocturnal sleep, Friedmann, Globus, Huntley, Mullaney, Naitoh, and Johnson (1977) concluded that "Subjective fatigue appears to be the limiting factor in determining the tolerability of gradual sleep restriction" (p. 245). This is consistent with the feeling of satisfaction that each of us has experienced following a good night's sleep, that contrasts so sharply with the enervating experience of increasing fatigue, the progressive difficulty of sustaining effort, and the acute discomfort that soon follows lack of sleep.

Though it is possible to document the effects of even a single

night of partial sleep loss using complex vigilance tasks over many hours (Wilkinson, Edwards, & Haines, 1966), the difficulty of demonstrating the effect objectively needs to be juxtaposed with the ease with which an individual is able to correctly identify that he is fatigued and unable to work at peak efficiency. Therefore, our approach to the study of how short periods of sleep can prevent decrement in performance and physiological functioning includes not only behavioral and physiological measures, but also extends to the investigation of subjective changes, since these reflect much earlier the processes which ultimately interfere with effective functioning. We believe that appropriately studied subjective reports are the most efficient way of tapping the universally acknowledged consequence of sleep loss. Indeed, in the absence of fatigue no decrements in functioning have ever been observed following sleep deprivation.

The thrust of our studies has been to explore the effectiveness of short periods of sleep -- naps -- as a means of preventing the debilitating effects of sleep loss. We have been impressed with the importance of individual differences in sleep patterns and have felt that unless these are adequately understood and taken into account, a proper evaluation of napping to reduce or prevent fatigue cannot be undertaken. In this report we will cover three major areas:

I. An overview of nocturnal sleep and daytime napping patterns in normal adults with a brief review of recent relevant reports of naps as a means of recovery from fatigue. This will be juxt posed with salient aspects of our previous work on napping p... rns in young adults. This

section will conclude with a review of <u>prophylactic napping</u> as a concept and the role it may play in facilitating continuous performance for sustained periods without the opportunity for prolonged periods of sleep.

II. Additional findings relevant to the study in progress. This section begins with a discussion of sleep efficiency during napping and the various indices of sleep efficiency which may be relevant to an understanding of daytime sleep. We present data concerning the relationship between objective sleep efficiency and subjective satisfaction as well as findings on physiological nap efficiency and delta sleep onset in individuals with different napping patterns. A further analysis of oral temperature data indicates that this parameter may be considerably more important than we have thus far recognized in mediating some of the differences between non-nappers and nappers. Finally, there is a discussion of new data concerning factors which aid and hinder sleep in a young adult population. The latter are particularly important in identifying an objectively innocuous environment hostile to napping.

III. Rationale for modifications in the design of the ongoing study based on the above findings and current pilot studies. A detailed description of the investigation currently in progress is provided. This includes initial screening of volunteers for the study as well as detailed descriptions of the experimental design, purposes and procedures for the psychological, behavioral, and physiological measurements taken both within and outside of laboratory nap sessions. New dependent measures which include performance, subjective and objective aspects of activation, and indices of diurnal rhythms are explicated. A brief

overview of the data that will be required prior to the implementation

of prophylactic napping is provided and concludes with an assessment

of the contribution of the current research in this context.

I. Napping and Recovery from Fatigue

A. Nocturnal Sleep and Napping Patterns in Adults

The thrust of our ongoing work has been concerned with the prevention of sleep loss effects through the systematic use of naps. We are attempting to understand the degree to which naps can provide more efficient sleep, and thus facilitate recovery from fatigue and enhance performance. An important component of such an investigation is a thorough realization of the frequency and duration of adult sleep patterns. Although this area has recently begun to receive attention, the focus here will be on relevant findings concerning adult sleep behavior.

In contrast to dramatic changes in nocturnal sleep duration and sleep staging during childhood and late adulthood (Feinberg & Carlson, 1968), the length of nocturnal sleep during the first half of adulthood is relatively constant, averaging a small decline from 7.5 hours to 7 hours between 18 and 50 years of age (Tune, 1969; Webb, 1971). It is noteworthy that these sleep length values are averages and thus do not reflect the vast individual differences in nighttime sleep length. This is amply illustrated in Webb's (1971) finding that slightly more than half of over 4,000 college students averaged nightly sleep durations either longer or shorter than the proverbial 7 to 8 hours.

More important for the understanding of versatility in adult sleep patterns is the surprisingly high frequency of daytime naps in college populations. Depending on whether surveys or sleep logs are used, and how the questions are asked, somewhere between 60% and 85% of the college population naps at least once a week (Lawrence, 1971;

Webb, 1975; Evans, Cook, Cohen, Orne, & Orne, 1977). It is worth noting that a low frequency of napping has been reported in a 20-year-old non-college working population (Webb, 1975). This would seem to indicate that the likelihood of napping is affected by the opportunity for this activity during waking hours. Thus, the evidence obtained from college students and other groups who are able to sleep ad libitum (Webb, 1975) suggests that a large proportion have the ability and inclination to utilize napping as a way of partially satisfying their sleep requirements.

The relationship between nighttime sleep and daytime napping is reflected in a negative correlation between napping frequency and nocturnal sleep length and a positive correlation between napping frequency and variability of nighttime sleep (White, 1975). This is congruent with out finding that a category of nappers consistently naps when they have either experienced a shorter than usual night's sleep or anticipate sleep loss.

B. Short Sleepers and Shortened Sleep

While individuals sleep on the average between 7 and 8 hours a night, there is much variability, and some individuals manage with a great deal less. There is no intrinsic reason therefore why one should assume how much sleep is needed to prevent the emergence of deprivation effects, and yet this is a central question if we wish to address the use of naps to facilitate continuous performance.

Scientific investigations of both short sleepers and shortened sleep in normal sleepers have provided rather consistent findings on

the nature of short nocturnal sleep periods. Adult nocturnal sleep has been reported in four cases to average less than four hours a night, though this is extremely rare (Jones & Oswald, 1968; Meddis, Pearson, & Langford, 1973; Dement, 1974). Still, about 9% of the young adult population averages less than 6.5 hours of sleep per night (Webb & Friel, 1971). From our perspective on the recuperative value of brief sleep periods, what is important is that these "short sleepers" have fewer awakenings and less time in transition stages of sleep, while getting as much stage 4 sleep as both normal sleepers (7.5 hours) and "long sleepers" (9.5 hours) (Webb & Agnew, 1970; Webb & Friel, 1971; Hartmann, Baekeland, & Zwilling, 1972). It is reasonable to assume that "short sleepers" are more efficient in obtaining the needed components of sleep.

Though such natural short sleepers are of interest, they are the exceptions to the rule. More relevant to understanding the role of short sleep periods in recovery from fatigue are studies of shortened nocturnal sleep in people who typically average normal sleep lengths. Until recently, little information was available on this topic.

The two most comprehensive studies on shortened nocturnal sleep in adults have involved reducing sleep from an average of 7.5 hours to 5.5 hours per night and maintaining the restricted schedule from 2 months to a year (Webb & Agnew, 1974; Mullaney, Johnson, Naitoh, Friedmann, & Globus, 1977). Results from both investigations are amazingly similar. Reduced sleep length produced relative increases in stage 4 sleep and concomitant decreases in stages wake, 2, and REM, which, of

course, is reminiscent of the high sleep stage efficiency of short sleepers (who typically obtain approximately the same amount of stage 4 as long sleepers). No measurable changes in either performance or mood were observed consequent to sleep restrictions, but subjective fatigue was profound and persistent for many weeks into the studies, although it eventually returned to baseline levels while sleep remained shortened (Friedmann et al., 1977).

These studies clearly suggest that the amount of sleep needed for long term effective functioning can within certain limits be reduced. This is accompanied by physiological alterations in sleep patterns, which over a period of time allowed subjects to function without fatigue despite a reduction of 1 to 2 hours of sleep per night. Though such training is of potential interest, the amount of reduction possible appears to be quite limited and even that requires a relatively long period of adaptation. From the point of view of continuous performance, this type of sleep discipline is likely to have limited utility. Further, it does not address the question of the amount of sleep needed to maintain effective functioning over a relatively short period of days. The approach to continuous performance which appears to us most promising involves the systematic use of napping. From this perspective the question emerges whether it is necessary to obtain sleep in one continuous period, and to what extent segmenting sleep time can serve to satisfy sleep need.

C. Fragmented Sleep Regimes and Napping Sleep

In recent years, from an entirely different theoretical perspective,

investigators have studied short, regularly intermittent sleep periods by an extreme fragmenting of the typical 24-hour cycle into 6 to 8 very short cycles -- for example, 1 hour sleep and 2 hours wake, or 30 minutes sleep and 1 hour wake -- in which subjects were required to sleep repeatedly throughout the day (Weitzman, Nogiere, Perlow, Sassin, McGregor, Gallagher, & Hellman, 1974; Webb & Agnew, 1975, 1977; Moses, Hord, Lubin, Johnson, & Naitoh, 1975; Carskadon & Dement, 1975). These studies report that subjects can sleep during the rapidly recurring short sleep periods, and though sleep efficiency (total sleep time/total bed time) is slightly lower than normal nocturnal sleep, sleep stage efficiency (relatively increased delta sleep and decreased transitional sleep) is high, as in short sleepers and shortened sleep. The slight increase in wakefulness during the sleep periods of these studies was found to be related to both circadian effects and the degree to which prior wakefulness was reduced. Since these investigations essentially allow for the full daily requirement of sleep, it is perhaps not surprising that post-experimental sleep after these fragmented regimes typically does not show any physiological evidence of accrued sleep deficit.

The forced nature of the 1:2 sleep:wake ratio in such studies, as well as the absolute amount of sleep allowed, makes them difficult to interpret in the context of naps as a means of recovery from fatigue. Though such paradigms are important from a theoretical point of view, they lack much relevance to the real world, since no one works a 60-minute "day" 16 times every 24 hours! Most important, however, these

investigations do not take into account individual differences in napping patterns.

The latter issue is equally relevant to the studies most frequently cited to support the widely held view that almost any change in the monophasic night sleep pattern of individuals is at least less efficient if not seriously deleterious (this would include shortened, lengthened, or displaced sleep). Whereas this view may prove correct, the support for it derives from studies of changes in nocturnal sleep schedules (Taub & Berger, 1973a: 1973b) and not from investigations of napping. In fact, in the Taub and Berger studies, subjects with a history of daytime napping were deliberately excluded from their experiments.

In contrast, improvement in both performance and psychological functioning following a nap period has been the model used in our past research to clarify the benefits of naps for recovery from fatigue. A study of habitual young adult nappers recently employed just such an approach. Following both a one-half hour and a two-hour nap, they observed increases in performance, subjective arousal, and some physiological parameters above pre-nap baselines (Taub, Tanguay, & Clarkson, 1976; see also Taub, 1977). These results are gratifying from our point of view, since they not only are congruent with our own data -- presented in previous reports and later sections of this report -- but also support the utility of our model for the study of behavioral-subjective improvements following naps.

Most directly relevant to our interests, however, is the question: given a reduced amount of total sleep, will several naps more effectively

prevent the deleterious effects of sleep deprivation than an equal amount
of continuous sleep? Hartley (1974) carried out a study comparing the
benefits of three 80-minute naps to one continuous 4-hour sleep period,
and reported that performance was maintained significantly better on the
nap regime. This finding suggests that naps can indeed be used to
maintain performance when the absolute amount of sleep is sharply re-
stricted.

D. Individual Differences in Napping Patterns

As we have reported previously, we have been able to isolate
two types of habitual nappers. One group, replacement nappers, naps
in order to compensate for lost sleep, while the other group, appetitive
nappers, naps regardless of the amount of sleep they might have had,
apparently because the nap gratifies some psychological needs. These
subgroups, originally identified using questionnaire techniques with
large subject populations, could be further delineated by means of in-
depth interviews. When the laboratory naps of appetitive nappers, re-
placement nappers, and habitual non-nappers were compared, consistent
physiological differences were observed. Sleep Diary data obtained on
these same subjects was congruent with the differences reported on the
questionnaires and individual interviews, as well as their physiological
patterns seen during the laboratory nap.

Further data on these differences will be presented in a later sec-
tion of this report. From the point of view of this discussion, we want
to emphasize that it is extremely difficult to draw definitive conclusions
from the body of literature on changes in sleep patterns, fragmented

sleep, or the potential of naps to alleviate fatigue, without taking into account the naturally occurring differences among individuals' napping patterns. Because of the implications of individual differences for the utilization of naps to facilitate performance under circumstances of minimal sleep opportunities, it was clearly necessary to validate and extend our observations, particularly since certain types of naps seem far more relevant than others. Further, the implementation of prophylactic napping will ultimately make it necessary to develop techniques to train individuals in the skill of useful napping.

E. Prophylactic Napping

Our interest in napping as a means of alleviating subjective fatigue and of enhancing motivation and performance in individuals restricted to irregular and limited sleep opportunities is based on the theoretical position that fulfillment of sleep need may be more flexible than is generally believed. We have often drawn an analogy between the need to sleep and the need to eat in order to illustrate that sleep, like nutritional requirements, can be satisfied in a variety of ways.[*]

Napping appears to us to be a particularly common way in which young adults with flexible schedules complement their sleep requirement. Moreover, we were struck by Webb's (1975) report of frequent development of naps in subjects engaged in ad libitum schedules of sleeping

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[*]This is strictly a conceptual analogy. In no way do we mean to imply that the neurophysiological substrate of sleep is functionally similar to food intake control systems. In addition, although we believe we were among the first to consider sleep as analogous to nutritional needs, other investigators, especially Webb (1975) and Johnson, et al. (1977) have also alluded to such an analogy.

and waking, as well as the perhaps apocryphal but ubiquitous anecdotal evidence of individuals functioning almost continuously for long periods of time by "snacking" their sleep through the expedient of short naps (for example, Napoleon, Edison, and Churchill). The third and most compelling evidence for the use of naps as a means to recuperate from sleep loss came from our own experiments, where what subjects described, and indeed what we observed in sleep diary data, was that naps were used by many people to alleviate the fatigue resulting from missed sleep. We called these replacement naps since they tended to follow sleep loss and therefore presumably served to make up for the missed sleep. What intrigued us even more was that on occasion replacement nappers appeared to nap in anticipation of sleep loss the following night (though this was less frequent than napping after sleep loss).

These preliminary observations led us to propose that naps may serve as a prophylactic to prevent the effects of sleep deprivation. In other words, we suggested that naps may be a way one could efficiently capitalize on an opportunity to sleep prior to periods that require wakefulness. We suggested that individuals who were required to perform on a quasi-continuous basis, with limited and undesirable sleep opportunities, would be able to function more effectively if they were trained to nap before periods of sustained activity and during occasional slack times, which would provide a possible but less than desirable occasion for napping.

We conceived of continuous performance in a military context as a situation which generally has at least some slack times during which a soldier could rest; however, these are periods of unknown duration, under

circumstances of potential danger, and in an environment not conducive to sleep. Consequently the soldier placed in such an environment would tend to stay awake in the hope that the demand for continuous performance would terminate and he would try to postpone sleeping until that time. Only when quasi-continuous performance has been required for an extended period does sufficient chronic fatigue develop for the soldier to take advantage of any sleep opportunity, regardless of its desirability. By that time the amount of sleep debt is sufficiently great that the naps which are obtained are never sufficient to restore optimal functioning. We have argued that individuals trained to nap prophylactically will utilize earlier sleep opportunities that would otherwise have been wasted, and in this fashion avoid or at least delay the development of a sleep debt sufficiently great to interfere with effective functioning.

Clearly, the concept of prophylactic napping must be put to an empirical test which we intend to do in the second part of the proposed studies. Though the utility of this concept is not yet widely shared, a recent review (Moses, 1978) of our research on individual differences in napping patterns commented favorably on the notion of prophylactic napping which was implicit in the reviewed study.

Before the concept of prophylactic napping can be implemented, however, it is equally important to evaluate the skill of different types of nappers to sleep in a hostile environment. For this reason the study currently under way is specifically designed to determine how well replacement nappers in particular are able to utilize a relatively undesirable napping environment.

II. Additional Findings Relevant to the Study in Progress

A. Sleep Efficiency During Napping

Our study of the utility of naps for enhancing both well-being and effective functioning in people required to sustain quasi-continuous performance has been directed toward increasing individuals' ability to sleep efficiently; that is, to maximize the benefits of sleep per unit time. The study of efficiency of sleep has recently gained popularity among researchers investigating fragmented sleep regimes. Though our napping studies were in a tradition purposively distinct from that which motivated the fragmented sleep studies, and as a result we are eager not to have it confused conceptually, it is nevertheless worthwhile to compare certain aspects of our data using approaches typically employed by others addressing the issue of sleep efficiency.

A common definition of efficiency in sleep is simply a ratio of the total sleep time divided by the total amount of time available to sleep (operationally, total bed time) (Webb & Agnew, 1975). For example, if someone is in bed for two hours for the purpose of sleeping, and in fact sleeps for 1.5 hours, their sleep efficiency is 1.5/2 or .75 (75%). While such a measure of sleep efficiency can provide an indication of how well someone utilizes an opportunity to sleep, it does not necessarily reflect the subjective impression of sleep length per time available to sleep. Consequently, we defined the traditional efficiency measure (total sleep time/total bed time) as physiological sleep efficiency, and in addition, calculated a subjective sleep efficiency

for our subjects by dividing the total amount of time they thought they napped in the laboratory by the total length of time they estimated they were in bed in the laboratory.

The upper half of Table 1 displays sleep efficiency means for appetitive nappers, replacement nappers, and non-nappers who slept during our 1-hour laboratory nap period. Physiological efficiency is further subdivided into total sleep after stage 1 onset and total sleep after stage 2 onset, since either stage may be used to define sleep onset. Examination of Table 1 reveals that both napper groups averaged higher physiological and subjective sleep efficiency ($p < .10$) than non-nappers, with replacement nappers being the highest. Since we limited the nap to a 60-minute total bed time period, it seemed inevitable that the significantly longer time it took non-nappers to fall asleep would result in decreased sleep efficiency. We therefore calculated two additional efficiency measures for how well subjects sustained sleep after sleep onset. These mean physiological and subjective sleep maintenance efficiency scores are presented in the lower half of Table 1.

Although subjective maintenance efficiency was not different among groups, physiological maintenance efficiency comparisons revealed that non-nappers were significantly more efficient at maintaining sleep once it had occurred than appetitive nappers ($p < .05$), with a similar trend evident when compared to replacement nappers. Extreme scores were not producing the differences among these

TABLE 1

Mean Sleep Efficiency Scores for all Subjects
Who Slept in each Group

	Sleep Onset	Appetitive (N=11)	Replacement (N=9)	Non-Napper (N=9)	t-test[e]
Physiological Efficiency[a]	Stage 1	.68	.70	.57	R, A > N*
	Stage 2	.59	.65	.53	R > N*
Subjective Efficiency[b]		.56	.57	.47	
Physiological Maintenance Efficiency[c]	Stage 1	.77	.79	.93	N > A, R*
	Stage 2	.75	.82	.93	N > A, R*
Subjective Maintenance Efficiency[d]		.81	.85	.88	

[a]Physiological Efficiency $= \dfrac{\text{Total Sleep Time (TST)}}{\text{Total Bed Time (60 mins.)}}$

[b]Subjective Efficiency $= \dfrac{\text{Total Time Asleep}}{\text{(Time to fall asleep)} + \text{(Total sleep time)} + \text{(Awake time after sleep onset)}}$

[c]Physiological Maintenance Efficiency $= \dfrac{\text{TST after Sleep Onset}}{\text{Total Bed Time after Sleep Onset}}$

[d]Subjective Maintenance Efficiency $= \dfrac{\text{Total Time Asleep}}{\text{(Total Sleep Time)} + \text{(Awake time after sleep onset)}}$

[e]All differences $p < .05$ (1-tailed) except where * indicates $p < .10$ for specific comparisons.

averages, since comparisons among median scores showed the same relationship. It is possible such a finding is due to the shorter amount of time non-nappers had available to sleep after sleep onset. To determine if this was accounting for the differences, we recalculated the nappers' physiological maintenance efficiency for the mean period of time after sleep onset that the non-nappers slept. The results showed the same relationship, namely, that non-nappers take longer to go to sleep during a nap, but once they fall asleep, they tend to stay asleep, at least within the time frame we allowed them. In contrast, nappers are more likely to fall asleep sooner (higher sleep efficiency), but have more awake time after sleep onset (lower maintenance efficiency), especially appetitive nappers.

Since physiological sleep efficiency is an index used by a number of investigators, it becomes possible to assess the comparability of our nappers' and non-nappers' physiological sleep efficiency to values reported in recent fragmented and napping sleep studies. Table 2 lists the sleep efficiency percentages (S. E. %) for our subjects' laboratory naps, and values from four recent studies of daytime sleep periods. It is noteworthy that our replacement nappers averaged a sleep efficiency very similar to the percentages reported by Moses et al. (1975) for a 1-hour sleep period every 3.7 hours, and by Lawrence (1971) for both 1/2-hour and 1-hour naps. The data from Webb and Agnew (1975) are for considerably longer sleep periods, and, given comparable sleep onset periods, the longer one sleeps, the higher the

TABLE 2

Physiological Sleep Efficiency[h] for Fragmented Sleep and Napping Sleep Studies

Webb & Agnew (1975)[ac]			Moses et al. (1975)[bc]			Taub et al. (1976)[bc]			Lawrence (1971)[ad]			Unit for Experimental Psychiatry; Study of 1-hour Naps in Nappers and Non-nappers			
Paradigm (#Ss=15)	Regime (hrs.)	S.E. (%)	Paradigm (#Ss=10)	Regime (hrs.)	S.E. (%)	Paradigm (#Ss=18)	Regime (hrs.)	S.E. (%)	Paradigm (#Ss=18)	Regime (hrs.)	S.E. (%)	Paradigm (#Ss=29)	Group[a]	S.E.[a] (%)	S.E.[b] (%)
Fragmntd. Sleep/ Wake Schedule on 1:2 Ratio	3:6	80	Fragmntd. Sleep/ Wake Schedule on 1:2.7 Ratio	1:2.7	61	Habitual Nappers Nap after "Normal" Night's Sleep	½ hr.	79	Habitual Nappers Nap after "Normal" Night's Sleep	½ hr.	64	Habitual Nappers & Non-naps. Allowed 1 hr. to Nap in Afternoon after "Normal" Night's Sleep	AN[e]	68	59
	4:8	85					2 hrs.	90		1 hr.	66		RN[f]	70	65
	6:12	88		"Normal" Night	94					2 hrs.	82		NN[g]	57	53
	8:16	93													
	10:20	92													
	12:24	38													

[a] Sleep onset defined as Stage 1 sleep.

[b] Sleep onset defined as Stage 2 sleep.

[c] Subjects were restricted in sleep length.

[d] Subjects were unrestricted in sleep length.

[e] Appetitive Nappers (N=11) who slept.

[f] Replacement Nappers (N=9) who slept.

[g] Confirmed Non-nappers (N=9) who slept.

[h] Physiological Sleep Efficiency = (Total Sleep Time) / (Total Bed Time)

physiological efficiency. On the other hand, the sleep efficiency

percentages for 1/2-hour and 2-hour naps of Taub et al. (1976) are con-

siderably higher than equivalent periods in all other studies, probably

because their subjects were well adapted to the laboratory by virtue

of three successive visits.

B. Relationship Between Objective Sleep Efficiency, Subjective Satisfaction, and Recovery from Fatigue

The concept of sleep efficiency implies that physiologically

efficient sleep will most expeditiously bring about the beneficial effects

of sleep. In order to evaluate this untested assumption, we correlated

our nappers' and non-nappers' physiological and subjective efficiency

scores (also maintenance efficiency) to their ratings of nap satisfaction

and recovery from fatigue both immediately after the nap (first) and about

30 minutes after the nap (second). Table 3 presents the resultant corre-

lation coefficients for all 33 subjects (11 appetitive nappers, 10 replace-

ment nappers, and 12 non-nappers), and the subgroup of 29 subjects

(11 appetitive nappers, 9 replacement nappers, and 9 non-nappers) who

slept during the laboratory nap period. Significant positive relationships

were apparently found between both physiological and subjective sleep

efficiency and nap satisfaction and recovery from fatigue, but these were

the result of the inclusion of four subjects who had not slept at all.

These four subjects by definition had zero physiological sleep efficiency,

and since they did not sleep, they were hardly likely to rate their nap as

satisfying. Consequently, their data serve to distort the distribution.

TABLE 3

Pearson Correlation Coefficients between Sleep Efficiency and Subjective

Recovery from Fatigue

	N	Nap Satisfaction		Feeling Now vs. Before Nap	
		First[a]	Second[b]	First[a]	Second[b]
Physiological Efficiency					
All subjects	33	.40*	.41*	.24	.35*
Sleepers only	29	.19	.15	.11	.25

a   Asked immediately after the nap.

b   Asked approximately 30 minutes after the nap.

* $p < .05$ (2-tailed).

When only subjects who slept were included in the correlation, the relationships did not even approach significance.

It would appear that the physiological efficiency of napping sleep is not necessarily related to the subjective benefits derived from naps. While such a conclusion might not hold for nocturnal sleep or long periods of daytime sleep, it does support our assertion that subjective sleep satisfaction must be assessed before reaching conclusions regarding the effectiveness (or ineffectiveness) of naps based only on physiological criteria.

C. Nap Efficiency and Delta Sleep Onset

In our earlier reports, we showed clear differences between appetitive nappers on the one hand versus replacement nappers and non-nappers on the other. The differences between nappers and non-nappers, however, were primarily in the length of sleep onset (a difference which is, of course, reflected in the physiological sleep efficiency measure). Further analyses revealed an interesting additional difference concerning the rapidity with which non-nappers entered delta (stage 3-4) sleep.

Tables 4 and 5 show mean delta sleep latencies for stage 1 and stage 2 sleep onsets respectively, for nappers and non-nappers who had delta sleep. What is striking is that despite the fact that non-nappers averaged a significantly longer time to fall asleep during the nap (mean stage 1 onset = 17.6 mins.) than replacement nappers (mean stage 1 onset = 6.5 mins.), they averaged a significantly shorter time going from sleep onset to delta sleep (mean stage 1 to delta sleep onset =

TABLE   4

**Mean Time (Minutes) to Stage 1,
Between Stage 1 and Delta Sleep, and to Delta Sleep**

	Appetitive (N=8)	Replacement (N=8)	Non-Napper (N=7)	$\underline{t}$-tests[a]
Stage 1 Onset	6.9	6.5	17.2	N > A, R
Stage 1 to Delta	25.7	28.6	20.4	R > N*
Delta Sleep Onset	32.6	35.1	37.6	

[a]All differences $\underline{p}$ < .05 (2-tailed) except where * indicates $\underline{p}$ < .10 for specific comparisons.

TABLE   5

**Mean Time (Minutes) to Stage 2,
Between Stage 2 and Delta Sleep, and to Delta Sleep**

	Appetitive (N=8)	Replacement (N=8)	Non-Napper (N=7)	$\underline{t}$-tests[a]
Stage 2 Onset	13.0	10.7	19.4	N > R*
Stage 2 to Delta	19.6	24.4	18.2	
Delta Sleep Onset	32.6	35.1	37.6	

[a]All differences $\underline{p}$ < .05 (2-tailed) except where * indicates $\underline{p}$ < .10 for specific comparisons.

20.4 mins.) than replacement nappers (mean stage 1 to delta sleep onset = 28.6 mins.); consequently, their mean time for delta sleep onset from the instruction "Go to sleep" was only 2.5 minutes longer than replacement nappers! We do not view this a spurious finding, since non-nappers' stage 1 to delta variance is very low (s.d. = 4.5 mins.) and the replacement nappers' stage 1 to delta onset mean (28.6 mins.) agrees closely with Lawrence's (1971) 1-hour nappers' mean (28.5 mins.).

We suspect that the non-nappers' rapid onset of delta sleep, low sleep stage cycling during the nap (see 1975 Progress Report), and high physiological sleep maintenance efficiency during the nap are indicative of a tendency to engage in a highly consolidated, nocturnal-like sleep pattern when napping, and because of this, the relatively brief nature of the nap then produces dissatisfaction and, paradoxically, increased fatigue. That is, for the non-napper, being awakened from a brief daytime nap may be much like being awakened at night shortly after having fallen into a sound sleep -- a feeling that is not particularly pleasant. While this offers a conceptual framework for why daytime naps may be unpleasant for some non-nappers, it does not explain what predisposes the non-napper to have difficulty napping, and conversely, it does not account for how nappers are able to fall asleep quickly when they nap and awake refreshed, thus avoiding the non-nappers' predicament. Examination of arousal differences between nappers and non-nappers immediately prior to their laboratory nap seems to provide some interesting clues.

D. Napper - Non-napper Differences in Oral Temperature and their Relationship to Sleep Efficiency

In an earlier report, we briefly noted differences among replacement nappers, appetitive nappers and non-nappers in oral temperature prior to and following a mid-afternoon nap. Figure 1 illustrates the mean oral temperature taken sublingually, for all subjects in the napper and non-napper groups.*

While both replacement nappers and non-nappers showed a mean decrease in temperature ($p < .05$ and $p < .01$, respectively), no such difference is seen in appetitive nappers. Further, appetitive nappers did not show a positive correlation between pre- and post-nap temperatures, though both replacement nappers and non-nappers showed such a relationship (by coincidence, $r = .57$, $p < .10$ for each of the groups). The appetitive nappers display a physiological uniqueness in their response to napping, supporting our view that for them it is functionally and physiologically a different event from what it is for either replacement nappers or non-nappers.

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*We examined temperature data for differences as a function of sexual composition of each group, to insure that this variable was not accounting for our results. We found that females averaged a nonsignificant but slightly higher pre-nap oral temperature than males -- both for total subjects, as well as within each group. Non-nappers had more males ($N = 6$) than females ($N = 3$), while the converse was true for appetitive nappers (males = 4, females = 6), and replacement nappers (males = 4, females = 5). Given that females averaged a slightly higher temperature than males, and that nappers had a few more females than males (contrary to non-nappers), one might predict nappers to have a higher mean oral temperature than non-nappers. This was clearly not the case. In fact, non-nappers averaged the highest pre-nap oral temperature. This rules out sex differences as accounting for the temperature data, and further compels us to accept the legitimacy of our napper - non-napper differences.

Sub-Lingual Temperature (°F)

Appetitive Nappers
Non-Nappers
Replacement Nappers

Pre-Nap 0 min.
Post-Nap 60 mins.

98.8
98.6
98.4
98.2
98.0
97.8
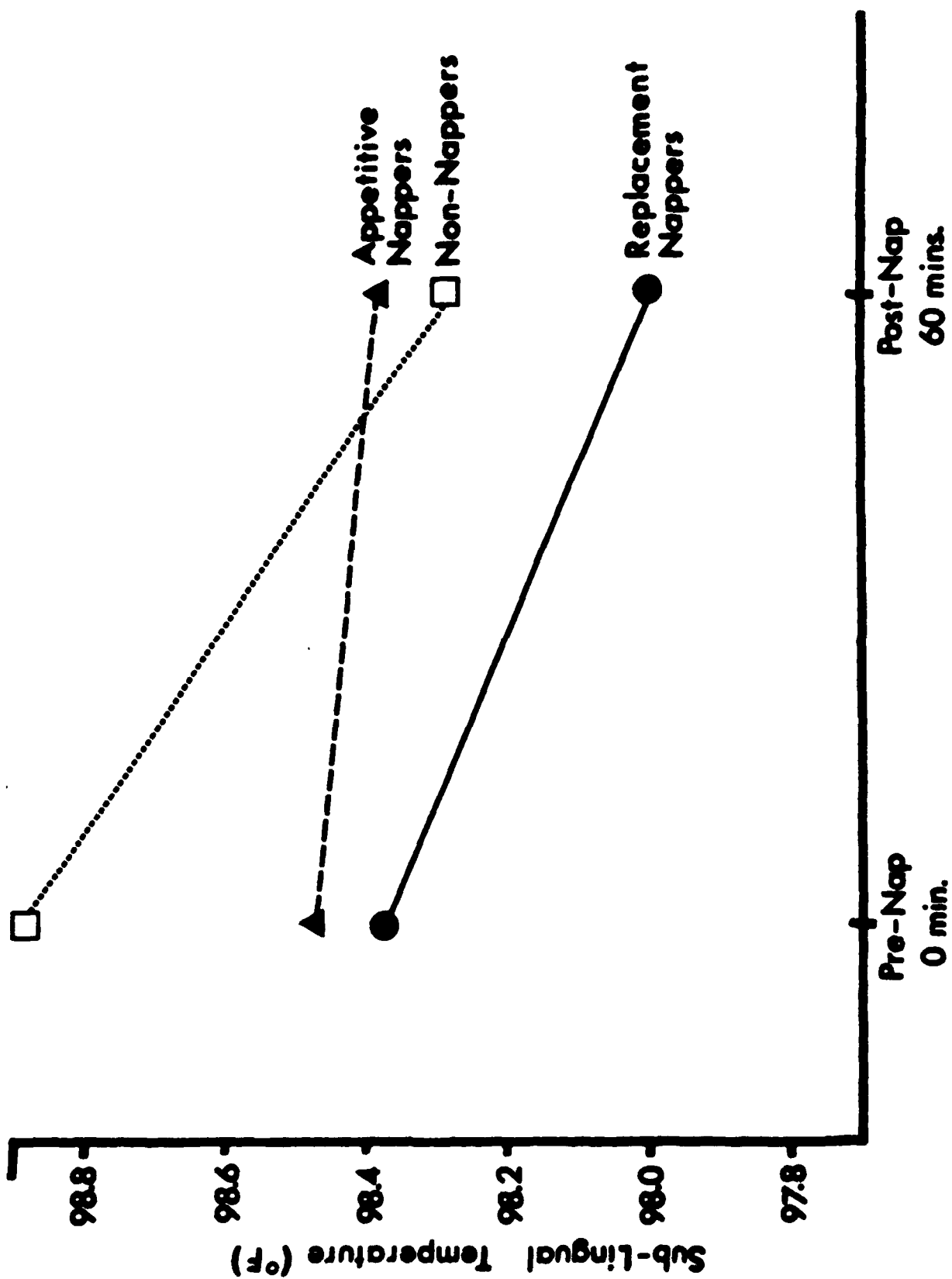
FIGURE 1

Though these data -- based on changes in oral temperature during the nap -- are interesting, on careful examination the pre-nap temperature turns out to be a more relevant measure. It relates directly to the sleep efficiency measures we discussed ear.   since two recent fragmented sleep studies have found that within individuals' circadian cycles, physiological sleep efficiency was lowest wher body temperature was highest, and vice versa (Weitzman et al., 1͡͡4: Moses et al., 1975). With our subjects, the correlation between pre-nap temperature and physiological sleep efficiency is r= -.37, p <.05 for all subjects.

It should be noted that this analysis includes the four subjects (1 replacement napper and 3 non-nappers) who failed to go to sleep in the laboratory. It is appropriate to include them here because we are seeking to evaluate the relationship between two physiological param-eters, both of which are on a continuum. Sleep efficiency may range from 0 (no sleep) to a value approaching 100%. The four subjects who did not sleep turn out to be among the highest pre-nap oral temperatures; their mean was 99.0°F versus a mean of 98.5°F for those subjects who slept. This suggests an important relationship between the level of arousal at the beginning of a nap, indexed by oral temperature, and the subject's ability to nap. Though the correlation between pre-nap oral temperature and physiological sleep efficiency is not significant when the subjects who did not sleep are excluded, it is well to remember that the non-nappers as a group had significantly higher oral temperatures

than the replacement nappers, and significantly lower sleep efficiency.*

This prompted us to plot the relationship between mean pre-nap oral

temperature and mean sleep efficiency for each of the three groups of

subjects, excluding those subjects who did not sleep. Figure 2

graphically illustrates this relationship using both stage 1 and stage 2

sleep onset criteria.

E. Oral Temperature and Subjective Arousal

Past work has established that there are significant differences

in sleepiness ratings prior to the nap between non-nappers and nappers.

Even more relevant is the change in subjective arousal following napping,

where neither appetitive nor replacement nappers show a meaningful

change from their pre-nap arousal even at the point immediately after

awakening. Non-nappers, however, reveal an increase in sleepiness

following arousal from the nap (see Figure 3).

The tendency of the pre-nap arousal ratings to be highest for the

non-nappers is paralleled by the tendency for the non-nappers to have

the highest pre-nap oral temperature. Since these two measures have

similar circadian periodicities (Colquhoun, 1971; 1972), and both have

----

*In an effort to find a precedent in the scientific literature for our
non-nappers' high mean pre-nap temperature, we settled on Monroe's
(1967) study of body temperature in "poor" and "good" nighttime sleepers.
Monroe reported that the "poor" nocturnal sleepers averaged .34°F higher
temperatures -- both before and during nighttime sleep -- than the "good"
sleepers, a figure that is surprisingly close to the .40°F average differ-
ence between our non-nappers and replacement nappers. We are not sug-
gesting that our non-nappers are poor nighttime sleepers -- certainly all
our data indicate their nocturnal sleep is like nappers' nocturnal sleep --
however, our non-nappers were selected on the basis of their history of
being "poor" daytime sleepers, and it is difficult not to be impressed and
intrigued by the analogous temperature differences reported by Monroe
(1967).
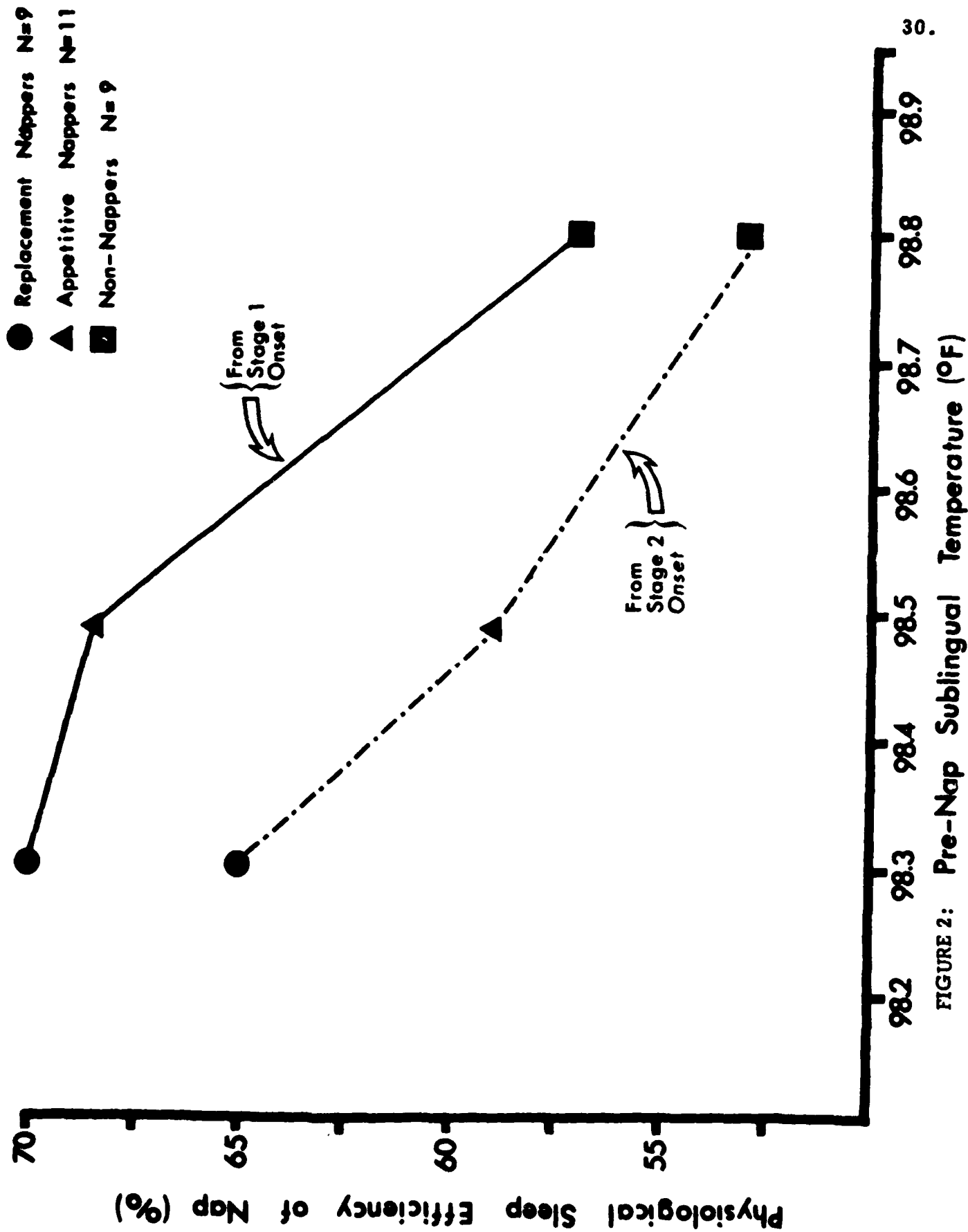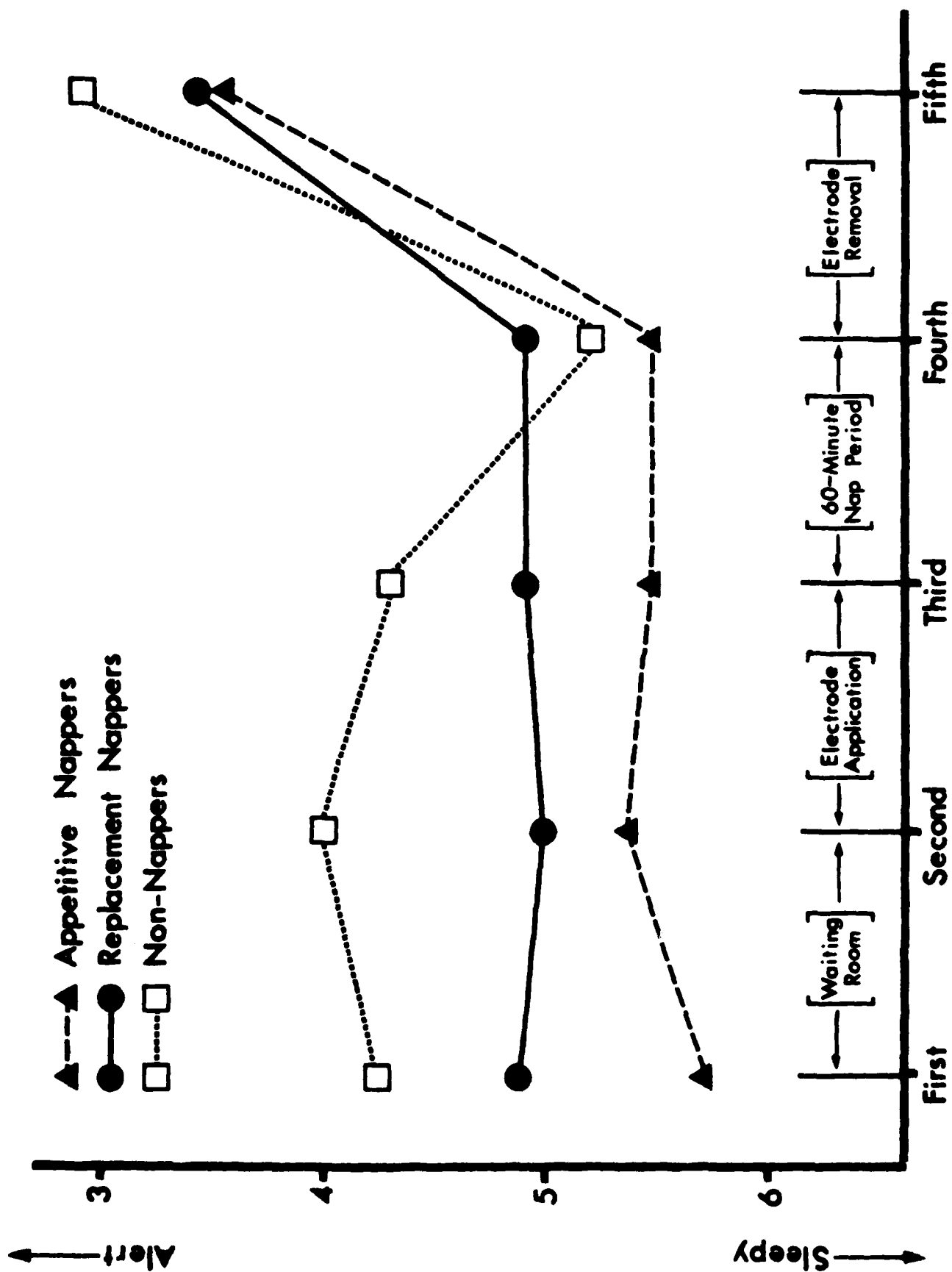
FIGURE 2: Pre-Nap Sublingual Temperature (°F)

Physiological Sleep Efficiency of Nap (%)

- ● Replacement Nappers N=9
- ▲ Appetitive Nappers N=11
- ■ Non-Nappers N=9

From Stage 1 Onset

From Stage 2 Onset

30.

Subjective Sleepiness Estimates

been reported to decline systematically during chronic sleep deprivation (Murray, Williams, & Lubin, 1958), we felt compelled to examine the relationship between pre-nap arousal and temperature in our data.

While appetitive nappers show a significant predicted negative correlation (r= -.52, p <.05) between these two variables, neither the replacement napper nor the non-napper group correlations were significant though both were negative. Since all three groups showed negative correlations, they were pooled and Figure 4 displays the resultant scatter plot. The correlation is not significant (r= -.21); however, the scatter plot suggests the relationship may be more robust than the coefficient indicates. Though technically the present data must be considered a chance result, we are not comfortable in accepting the null hypothesis. It would, after all, be quite surprising given unreliability of temperature measurements, the great inter-individual variability of temperature measures and the way the subjective measures are anchored, as well as the use of a single measurement, if we were able to account for a major portion of the variance in the data.

However, it is important for the potential utility of prophylactic napping to assess the real relationship between tonic changes in physiological arousal levels to equivalent changes in subjective arousal and physiological sleep efficiency. Thus, if physiological periodicity were to account for a major portion of the variance, serious doubts about the practicality of prophylactic napping would be raised unless it were possible to disrupt the relationship without the need to sleep deprive the subject. Consequently, we felt that more adequate measures to assess individual tonic activation levels, both physiologically and subjectively, should
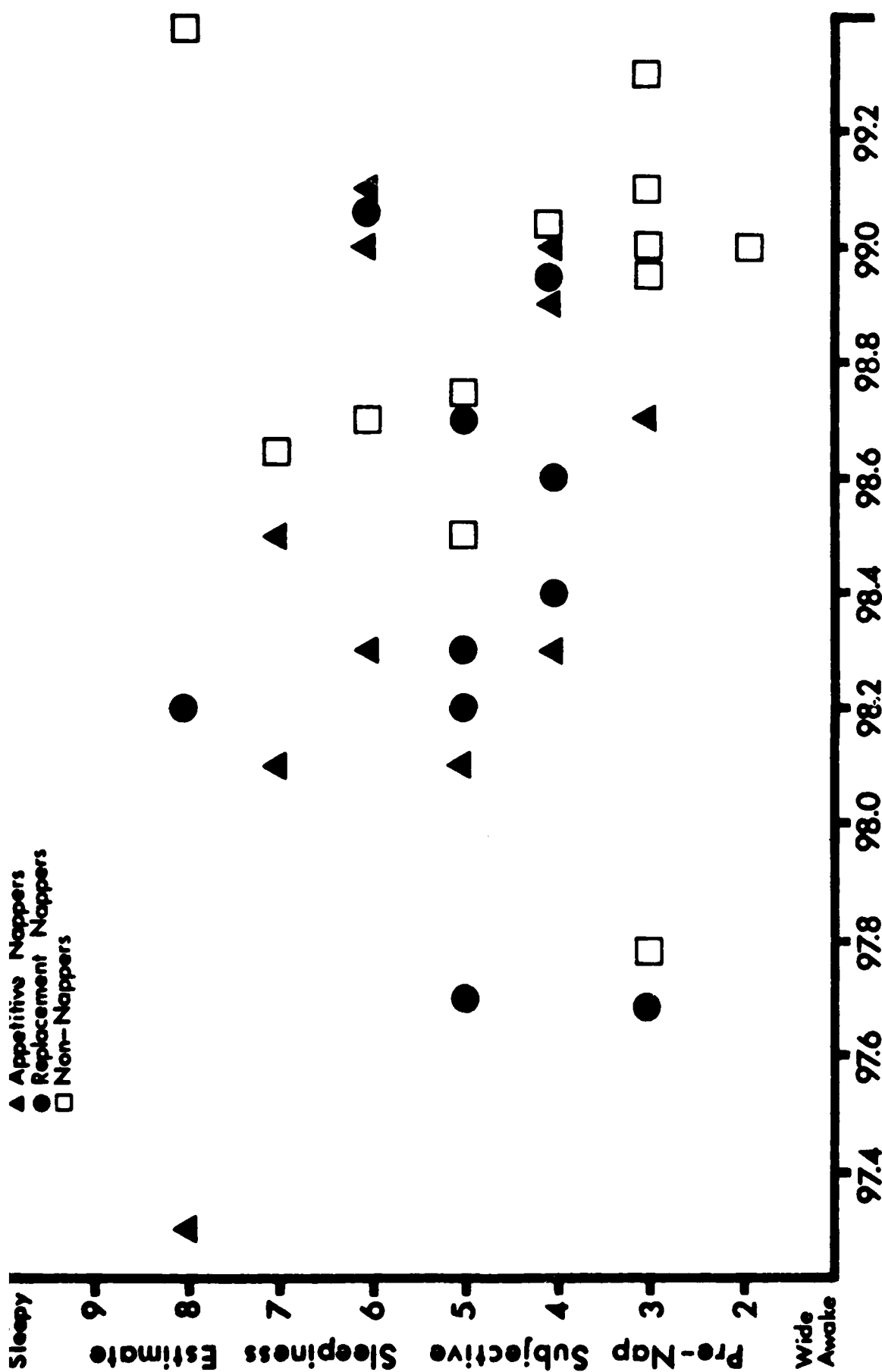
FIGURE 4: Pre-Nap Sublingual Temperature (°F)

▲ Appetitive Nappers
● Replacement Nappers
□ Non-Nappers

33.

properly be included in the present study. These necessary additions will allow a meaningful estimate of the relationship at a relatively modest cost. The modifications in the design to accomplish these goals are outlined in later sections of the report.

F. Aids and Deterrents to Sleep in Relation to Napping Types

Though significant differences could be demonstrated between different napping types and non-nappers in a variety of physiological and subjective dimensions, it was possible to create a napping environment sufficiently conducive to sleep that even among confirmed non-nappers 9 out of 12 slept in the laboratory on the first day without difficulty. The concept of prophylactic napping requires individuals to be capable of taking a nap whenever the occasion permits under circumstances which are not necessarily conducive to napping. Thus, it is important to compare groups with different napping patterns under these more realistic circumstances as well as in a situation which optimizes the opportunity to sleep.

It is surprising how little systematic work has been done on the control of sleep in more naturalistic settings. Aside from a few reviews of sleep in highly unnatural environments -- like space or Antarctica -- most published papers deal with the effects of noise and sound on sleep, and many of these are in reference to discrete, highly-controlled sounds, such as pure tones and names.

While such investigations have provided substantial information on arousal to stimulation during specific sleep stages, they have not

systematically addressed the effect on short periods of sleep, subjective satisfaction, or recovery from fatigue. Moreover, they have for the most part been confined to the study of nocturnal sleep periods and not to daytime naps, despite the fact that the latter are more likely to occur in circumstances which include external sleep inhibitors.

In an effort to gain some understanding of environmental and psychological factors that people report are likely to enhance or inhibit their control of sleep, we surveyed over 460 young adults, including our 33 laboratory nap subjects. Subjects were asked to "List as specifically as you can three special conditions which are <u>most</u> likely to help you sleep well," and in addition, "List three conditions you sometimes encounter under which you have a great deal of <u>difficulty</u> sleeping well."

Responses to both the <u>help</u> and <u>hinder</u> questions were grouped into one of nine general response categories, including six environmental (external) areas, and three intrapersonal (internal) areas.*

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*The 6 environmental categories were the same for both help and hinder response classifications. The 3 intrapersonal areas were expanded to 4 areas in the hindrance classification, by subdividing the affective disposition category into negative affect and excessive positive affect, thus producing 10 hindrance categories (see Table 7). Examples of representative responses in each category are as follows:

External Categories

	Temperature	Quiet	Darkness	Ventilation	Other Surroundings
Helps	Cool room	No noise	Light off	Fresh air	Lots of room
Hinders	Hot room	Noise	Light	Stuffy room	Dirty room

Internal Categories

	Affective Disposition		Physical Disposition	Cognitive Disposition
Helps	Good mood		Clothes off	Mentally relaxed
Hinders	(neg.) Tension	(ex. pos.) Too happy	Illness	Thinking too much

Tables 6 and 7 display the percentage of subjects who listed at least one response in each of the nine categories as a help or hindrance to sleeping well. The total number of subjects in each table is broken down into appetitive nappers, replacement nappers, and non-nappers, based on subjects' responses to our criterion napper-type questions. Italicized numbers in the tables refer to percentages of our laboratory nap subjects.

Table 6 presents the percentage of subjects who listed each category as a help to sleeping well. Categories were ranked in order of total percentage from highest to lowest. Examination of Table 6 reveals that responses falling into external (environmental) categories were listed by more subjects as aids to sleeping well than responses of internal (intrapersonal) categories.* Within each category, proportion tests revealed no significant differences between the large samples of appetitive nappers ($N = 52$), replacement nappers ($N = 200$), and non-nappers ($N = 172$), though the latter group tended to have a higher proportion of subjects listing temperature, quiet, and darkness as aids to sleeping well, with the converse being true for the bed category.

On the whole, percentages for our laboratory nap subjects (total $N = 33$, proportions in italics) showed the same relationships as the

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*Note that the total of all percentages in a given column of either Table 6 or 7 comes to over 100%. This is because subjects were allowed 3 responses for helps and 3 responses for hindrances. Consequently, any given subject would (if he filled in all 6 available blanks with 6 separate response categories, 3 help and 3 hinder) be counted as part of the percentage of all subjects in 3 help categories and 3 hinder categories. Ideally, the column totals for each group should be 300%, but a combination of blank answers and duplicate answers reduces the totals to about 250%.

TABLE 6

Percent of Subjects Listing Category as a HELP to Sleeping Well

Response Category (N=)	Total (424)	(33)	Appettitive (52)	(11)	Replacement (200)	(10)	Non-napper (172)	(12)	Proportion Tests**
Temperature	57	61	52	64	55	20	60	92	N > R
Quiet (No Sound)[a]	50	39	48	18	47	30	53	67	N > A
Bed[b]	44	33	52	55	45	40	40	8	
Darkness (No Light)[a]	42	51	37	45	39	50	46	58	A > N
Ventilation	23	12	19	9	27	20	20	8	
*Physical Disposition	18	18	19	18	20	20	15	17	
Other Surroundings	14	30	15	27	15	40	13	25	
*Affective Disposition	9	6	6	0	10	10	8	8	
*Cognitive Disposition	2	0	2	0	2	0	2	0	

*Internal help to sleeping well.

**All tests significant at $p=.06$ or higher. Italics indicate significant difference between laboratory nap groups, while bold type indicates significant differences between larger sample groups.

[a]The category refers to the absence of the variable as a help to sleep.

[b]Includes such items as the nature of the mattress, pillows, and sheets.

TABLE 7

Percent of Subjects Listing Category as a <u>HINDRANCE</u> to Sleeping Well

Response Category (N=)	Total (424)	(33)	Appetitive (52)	(11)	Replacement (200)	(10)	Non-napper (172)	(12)	Proportion Tests**
Sound	72	64	62	55	69	60	78	75	N > R,A
Temperature	60	61	63	55	63	70	55	58	
Light	33	30	13	18	33	30	39	42	N,R > A
*Negative Affect	28	30	35	36	27	20	27	33	
*Physical Disposition	23	24	21	27	26	20	19	25	
Bed	15	21	15	18	16	10	14	33	
Ventilation	9	3	6	9	7	0	12	0	
Other Surroundings	7	3	15	9	6	0	6	0	
*Excess. Positive Affect	5	15	10	9	2	20	6	17	A > R
*Cognitive Disposition	4	3	2	0	3	0	6	8	

*Internal hindrance to sleeping well.

**All tests significant at $p = .06$ or higher. Bold type indicates significant differences between large sample groups, while italics indicate differences between laboratory nap groups.

larger samples. An important difference, however, is shown in Table 6, where 11 of our 12 non-nappers (that is, 92%) listed external temperature as a help to sleeping well, compared to only 2 of 10 (20%) of our replacement nappers, p= .003. The appetitive napper proportion of 7 of 11 (64%) subjects fell in between these groups.

When we assessed the specific temperature response listed by each subject, we found that 75% (9/12) of the non-nappers indicated a <u>cool</u> temperature helped them sleep, compared to 55% (6/11) of the appetitive nappers, and only 10% (1/10) of the replacement nappers. The difference between the replacement nappers' and non-nappers' proportions remained significant (p= .009). Interestingly, such a finding is congruent with pre-nap oral temperature differences between these groups, detailed earlier in this report. That is, replacement nappers averaged the lowest pre-nap sublingual temperature, and as might be expected, almost none of them indicated that temperature -- let alone a cool temperature -- was relevant to sleeping well. Conversely, non-nappers averaged the highest pre-nap temperatures, and the majority of them indicated temperature, particularly a cool temperature, helped them sleep well. Appetitive nappers were midway between replacement nappers and non-nappers in both pre-nap temperature and proportion of subjects listing temperature as an aid to sleeping well.

The continuity between our subjects' self-report, obtained outside the laboratory, of (external) temperature aiding sleep, and our actual measurement of their oral (internal) temperature further supports our suggestion that body temperature differences found between replacement

nappers and non-nappers may mediate group differences in both the ability to nap and derive benefits from it, especially in non-nappers who typically find napping to be a difficult and unpleasant experience.

Table 7 displays the percentage of subjects who listed each category as a _hindrance_ to sleeping well. Similar to Table 6, categories were ranked in order of total percentage from highest to lowest. Generally, the ranks were the same as in Table 6, with the notable exception that the internal response categories of negative affect (e.g., anxiety, nervousness, worry) and physical disposition (e.g., exhaustion, illness, discomfort) moved up to rank immediately below sound, temperature, and light, as frequently cited hindrances to sleeping well.

A significantly higher percentage of non-nappers indicated that the presence of sound and/or light made it difficult to sleep well. In contrast, appetitive nappers had the lowest proportions in both sound and light hindrance categories, consistent with this group's reported ability to sleep in a variety of circumstances (e.g., on a plane, during a play, while reading). Though not significantly different, percentage comparisons between our laboratory nap groups (in italics) showed the same relationships within the sound and light categories as the larger subject samples.

The only other significant difference within the large samples occurred between appetitive and replacement napper groups' proportions in the category of excessive positive affect (e.g., excitement, excessive energy). Since both groups' percentages are small, the difference

is only 8%, and the laboratory group's proportions are in the opposite direction, it is doubtful whether this is a reliable or meaningful difference.

In sum, present findings clearly support our view that an environment which is lighted, has periodic sound distractors, and lacks the availability of a bed, thus preventing a prone position, is perceived by the young adult population as a setting unconducive to sleep. Consequently, the current study is incorporating these parameters in order to simulate an environment hostile to daytime napping.

III. Napping in Optimal and Hostile Environments: Study in Progress

A. Modifications in the Design of the Study

The findings discussed earlier in this report as well as the initial pilot studies clearly suggested the need to modify the study we have proposed in a number of ways. The most important alterations and their reasons are outlined below.

The relationship of the nap to tonic changes in arousal, body temperature, and ongoing sleep and napping patterns is an important issue which was not adequately dealt with earlier. For this reason, an adaptation day is added which makes it possible to obtain 7 days of sleep diaries prior to the first nap, to allow subjects to reach criterion levels of performance and provide appropriate baselines as well as to become familiar with the subjective scales to be used on the subsequent napping days. Further, the session provides a much needed control, and permits an added preliminary assessment of oral temperature in the laboratory. Finally, this initial day makes it possible to begin to obtain sleep diary data for one week preceding the experimental nap. Throughout the study the single pre- and post-nap temperature measures will be augmented with two additional temperature measures, one preceding the nap by some 45 minutes and the other following the nap by some 45 minutes.

The second day the subject comes to the laboratory will be planned as close to a week after the first session as possible. At that time the first 7 days of sleep diary data will be collected, and the subject will take the first nap under the optimal environment closely

resembling that of the earlier study. One week later the subject will come to the laboratory for a second nap in non-optimal circumstances.

The questionnaire data clearly supports our view that for the population of young adults the presence of light and noise as well as the inability to lie down in bed are important factors which should make napping considerably more difficult. We are seeking to explore the effects of these factors on napping behavior in our population, and while we expect some subjects in each group to be able to nap under non-optimal circumstances, we would anticipate that the hostile surroundings will be reflected both in the number of individuals who nap in each group and in the physiological sleep patterns of some of those individuals who do nap.

Following the second nap, subjects will be asked to provide sleep diaries for an additional two weeks. They will also be asked to cooperate in the difficult task of obtaining circadian measures by recording their level of arousal through the use of the Thayer Activation Scale and taking their temperature. Further, we hope to validate the sleep diary data by obtaining an ongoing measure of physical activity for at least two three-day segments during this period.

Finally, a fourth session is added as a control, to help assess possible practice effects on performance tasks, and to evaluate subjective changes following an equivalent wake period instead of the nap (during which subjects will carry out interpolated tasks). This session is also needed to collect the two-week sleep diary and circadian rhythm data, and to allow adequate opportunity for an in-depth debriefing.

As we have discussed in previous letter reports, it did not prove to be feasible to have the subjects take non-optimal naps in the same room in which they would have the optimal naps without destroying the ecological validity of the experiment. Thus, we went to considerable effort to prevent subjects from perceiving the various "random" noises in the hostile environment as intentional, and it was difficult to avoid that conclusion when the same physical set-up was used for both nap days. Similarly, it is quite a different matter to be asked to nap in a chair, if that is the best form of accommodation available, from being asked to nap in a chair when a comfortable bed is beside you.

Though somewhat obvious in retrospect, these are the kind of factors which can and all too often do interfere with the generalizability of findings. By using a different room for the two days we have succeeded in making the setting plausible, and consequently our results should be more readily generalizable. Overall, the study as it is now in progress, while demanding considerably greater effort than originally projected, will go a long way toward answering some of the basic questions which need to be resolved prior to the second set of studies which will involve the actual test of prophylactic napping. We anticipate that the study of prophylactic napping will be carried out with subjects from the present study who show consistent evidence of replacement napping.

B. A Detailed Outline of the Ongoing Experiment

1. Experimental Design. Figure 5 shows an outline of the experimental design. The study requires subjects to attend four separate 4-hour laboratory sessions over a 30-day period. The first three sessions

4-HOUR LABORATORY SESSIONS (Performance, sleepiness, and temperature are measured before and after each of the laboratory sessions.)	NON-LABORATORY MEASURES *		TIME (DAYS)
	SLEEP DIARY	MULTIPLE CIRCADIAN MEASURES	
DAY 1 Wake Control Period			1
	1-1		2
	1-2		3
	1-3		4
	1-4		5
	1-5		6
	1-6		7
DAY 2 Nap in Optimal Environment	1-7		8
	2-1		9
	2-2		10
	2-3		11
	2-4		12
	2-5		13
	2-6		14
DAY 3 Nap in Non-optimal Environment	2-7		15
	3-1	1-1	16
	3-2	1-2	17
	3-3	1-3	18
	3-4	1-4	19
	3-5	1-5	20
	3-6	1-6	21
	3-7	1-7	22
	4-1	2-1	23
	4-2	2-2	24
	4-3	2-3	25
	4-4	2-4	26
	4-5	2-5	27
	4-6	2-6	28
	4-7	2-7	29
DAY 4 Wake Control Period	5-1	3-1	30

* Non-laboratory measures are data collected by subjects at home. The circadian measures include oral temperature, Thayer Activation Scale, and body movement.

FIGURE 5

are separated by 1 week, while the fourth session follows 2 weeks after the third. The first three sessions for all subjects will be run in the afternoon, between 1 p.m. and 6 p.m., with the requirement that for a given subject the specific hour for the successive sessions be as close as possible. For example, a subject run at 3 p.m. on DAY 1 will be scheduled for 3 p.m. on DAYS 2 and 3 as well. This requirement should minimize confounding circadian effects within subjects.

Assessment of circadian differences between subjects will be accomplished by 2 weeks of multiple daily measures of oral temperature, subjective arousal, and body movement. These will occur after the first three laboratory sessions in order to avoid overloading the subjects. Daily sleep diaries will, however, be started immediately after the DAY 1 session, since this data is essential to document sleep patterns surrounding the two laboratory nap periods (DAYS 2 and 3).

The first and fourth laboratory sessions will serve as wake control conditions, the second session will require napping in optimal (sleep-conducive) surroundings, while the third session will require napping in a hostile environment. The order of the laboratory sessions will not be counterbalanced since any adaptation effects to the laboratory will work against the experimental hypothesis of validating napper - non-napper differences in the ability to nap in a hostile environment. That is, adaptation effects from the DAY 2 optimal nap session should increase the likelihood of sleep occurring in the subsequent DAY 3 hostile environment. Nonetheless we are predicting that most non-nappers will be unable to sleep, and possibly some replacement nappers will have

difficulty in sleeping on DAY 3. To counterbalance and reverse DAYS 2 and 3 would produce little information relevant to the thrust of these studies, but would essentially reduce our sample size by half. Thus the present design maximizes the likelihood of findings relevant to the practical issues.

2. _Initial Screening of Volunteers_. In order to select relatively pure types of replacement and appetitive nappers as well as non-nappers who find napping counterproductive rather than simply lacking the time to nap, it is necessary to survey a large subject population. Experience with this problem suggested a sample of approximately 600 subjects will provide the necessary number of individuals with relatively homogeneous napping patterns in each category.

While we are convinced that it is possible for appetitive nappers to engage in replacement napping and for many non-nappers to learn to nap productively, the type of studies being carried out here to validate the feasibility of prophylactic napping are best conducted with subjects whose patterns of napping are both clear-cut and stable. We obtained the cooperation of four large college classes and asked students to complete an extensive sleep questionnaire. We felt it important to obtain a high rate of response and thus offered subjects $2.00 to reimburse the hour's time needed for completion of these questionnaires, and to indicate their interest in participating as subjects in napping research.

In order to maximize commitment, we asked volunteers to sign a receipt for the $2.00, which they received _in advance_, along with a self-addressed envelope which included the questionnaires. Ninety-four

percent of the students volunteered to take home and complete the questionnaires. Of these 618 volunteers, 604 completed and sent back questionnaires -- a return rate of 98%. We believe that these very high rates of volunteering and returning questionnaires are related not only to the way the research is presented in class, but also to the procedure of paying subjects in advance for the work involved in completing the questionnaires. By placing trust in the subjects, their commitment tends to be increased, which not only yields a high rate of return but also facilitates their subsequent participation.

It is worth noting that the proportion of different napping patterns in this subject population is remarkably similar to those in our previous large samples. We suspect that this may be a function of consistently obtaining data on well over 90% of the total sample, thus minimizing the problems of selection bias.

3. Subjects. Based on sleep questionnaire classification, 26 replacement nappers, 26 appetitive nappers, and 26 non-nappers from a young adult (18 to 31 years of age) college population are being invited to participate in the study. In keeping with our previous work, subjects will be included only if questionnaire classification of napper type is confirmed by a blind in-depth interview conducted by a member of our staff. The sample sizes selected should insure that by the end of the four experimental sessions complete data will be available on at least 12 subjects in each group. In particular, we hope to maximize the number of replacement nappers completing the experiment, since it is from this group that we will draw subjects for the subsequent experiment to

test prophylactic napping.

4. <u>Measurements During Laboratory Sessions</u>. Figure 6 displays
an outline of the sequence of measurements taken before and after the
two experimental nap sessions (DAYS 2 and 3). Performance, subjective
arousal, and oral temperature are recorded four times: twice prior to the
beginning of each 60-minute nap period (about 1 hour before, and imme-
diately before), and twice following each nap period (immediately after,
and about 45 minutes after). The purpose of repeating measures both
before and after the napping sessions is to clarify the time course of
effective functioning preceding and following a nap. Though the same
sequence of measurements will be taken during both wake control ses-
sions (DAYS 1 and 4), measurements will occur only twice, once imme-
diately before and once immediately after the 60-minute wake periods.

(a) <u>Performance Tasks</u>. The performance tasks we are
including in the experiment were developed in our laboratory based upon
reports of task parameters found to be most sensitive to sleep loss
(Johnson & Naitoh, 1974; Naitoh, 1969). Our early investigations of
partially sleep-deprived subjects, as well as a collaborative study on
prolonged continuous performance (see 1975 Progress Report), have con-
firmed the sensitivity of these tasks to both sleep loss and recovery
sleep obtained through naps. The two tasks included are the Descending
Subtraction Test and the Random Number Generation Task; also included
is a behavioral reaction time measure.

(1) <u>Descending Subtraction Task</u>. The descending subtraction
test requires the subject to keep in mind and manipulate several items

SEQUENCE OF MEASUREMENTS TAKEN DURING

LABORATORY NAPPING SESSIONS (DAYS 2 & 3)

Pre-Nap

Initial Measurements
- Performance Tasks #1
- Subjective Sleepiness #1
- Oral Temperature #1
- Subjective Activation #1

Electrode Application (about 45 minutes)

Measurements Immediately Before
- Performance Tasks #2
- Subjective Activation #2
- Oral Temperature #2
- EEG, Heart Rate, & Electrodermal Baselines
- Subjective Sleepiness #2

"Go to sleep"
60-MINUTE NAP PERIOD
Telephone ring reaction time

Post-Nap

Measurements Immediately After
- Subjective Sleepiness #3
- Performance Tasks #3
- Subjective ratings of nap temporal characteristics, nap satisfaction, and recovery from fatigue.
- Subjective Activation #3
- Oral Temperature #3
- EEG, Heart Rate, & Electrodermal Baselines Telephone ring for electrodermal response.

Electrode Removal (about 30 minutes)

Final Measurements
- Performance Tasks #4
- Subjective Sleepiness #4
- Oral Temperature #4
- Subjective Activation #4
- Subjective ratings of nap satisfaction and recovery from fatigue.
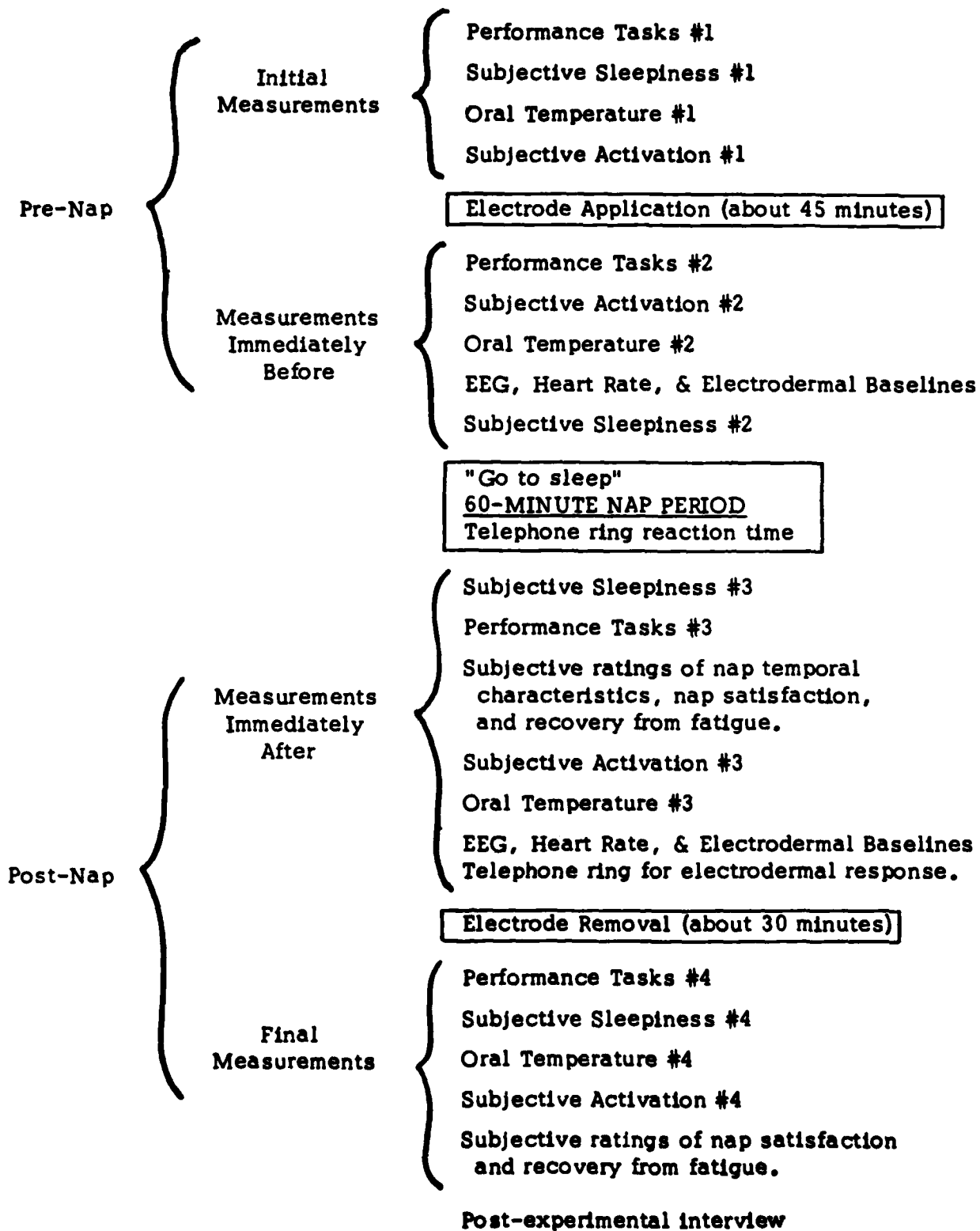
Post-experimental interview

FIGURE 6

of information simultaneously. The subject is given a 3-digit number, e.g., 736, and is asked to serially subtract 9, then 8, then 7, etc., from the previous progressive total, saying each successive total aloud. After subtracting 2, the subject begins a new cycle by continuing to subtract 9, etc. In order to accomplish the task successfully the subject must keep in mind the particular number he has just said as well as the number he needs to subtract -- both of the numbers being altered with each successive subtraction -- while working as fast as possible. Three major error categories are losing track of the original number, errors in subtraction, or errors in the choice of number to subtract. Thus, the task allows an assessment of both speed and accuracy.

(2) Random Number Generation. The random number generation task has been derived from our work on the measurement of the monitoring and deployment of human attention (Evans, 1978; Graham & Evans, 1977). The subject is asked to produce numbers between 1 and 10 at random in time with a metronome. The task demands that the subject keep in mind the numbers he has generated in the past -- in order to avoid using any given number more than another, or repeating a number too frequently.

(3) Reaction Time. Similar to our earlier investigations, the end of each 60-minute napping session will be signaled by a loud telephone ringing next to the subject. He will have been instructed before the session to answer the phone when it rings. The time it takes the subject to answer the phone is recorded as reaction time, and serves as a behavioral index of the degree of arousal and responsivity after an

hour of sleep or rest. We will also score physiological reaction time of sleeping subjects from the time the bell rings to EEG desynchronization.

(b) <u>Subjective Arousal Ratings</u>. Subjective arousal is assessed by a self-report scale of sleepiness -- used in our previous work -- as well as an adjective checklist of arousal (Thayer, 1967). Both scales are known to show increments in arousal following naps (Evans et al., 1977; Taub, 1977).

(1) <u>Sleepiness</u>. The subjective sleepiness scale which we developed and are using is similar to other traditional sleepiness scales (Hobbes, Zarcone, Smythe, Phillips, & Dement, 1973). It consists of a 10-point scale where 1 is "wide awake" and 10 is "very sleepy."

(2) <u>Activation</u>. Subjective activation is assessed by a 50-item Activation-Deactivation Adjective Check List that yields four unrelated measures: deactivation-sleep (fatigue), general activation (hyperactivity), general deactivation (calmness), and high activation (stress) (Thayer, 1967, 1970). A short 20-item version of the form, which basically includes the deactivation-sleep factor, has been reported to show decreases in fatigue following 1/2-hour and 2-hour naps (Taub et al, 1976). The short version will be used for repeated measurements before and after nap sessions.

(c) <u>Physiological Measurements</u>. The physiological parameters we are recording are the consequence of both our prior investigations of nap physiology -- such as oral temperature and EEG findings detailed in this report -- as well as new theoretical perspectives we

have developed concerning control of sleep onset and responsivity to stimulation. In particular, we are focusing on the EEG measures of sleep and wakefulness, electrodermal activity, heart rate, and oral temperature.

(1) <u>EEG and Related Sleep/Wakefulness Measures</u>. Electroencephalographic (EEG), electrooculographic (EOG) and electromyographic (EMG) recordings are made throughout both DAY 2 and DAY 3 60-minute nap sessions. While EEG provides information on the brain's state, the EOG allows assessment of both slow and rapid eye movements, and the EMG monitors skeletal muscle activity. These are the recommended standard parameters used for determining whether a subject is awake or drowsy, or the depth of sleep (Rechtschaffen & Kales, 1968). They are essential for recording sleep onset latency, sleep stage patterning and consolidation, sleep length, amount of various sleep stages, etc.

(2) <u>Electrodermal Activity and Heart Rate</u>. Inclusion of electrodermal activity and heart rate recordings into laboratory nap sessions (DAYS 2 and 3) is for the purpose of providing additional information on napper - non-napper differences in responsivity to stimulation during sleep. Since the non-optimal surroundings nap includes extraneous acoustic stimuli, as well as a loud awakening bell (the bell also occurs at the end of the optimal nap session), it is of some interest to address the issue of activation during naps in hostile environments.

(3) <u>Oral Temperature</u>. Before and after each laboratory session sublingual temperature is recorded by use of a basal thermometer. In addition, four Tempa-Dot readings will also be obtained during each

session. The intriguing oral temperature differences observed between nappers and non-nappers in previous work need to be extended and related to circadian rhythms.

(d) Subjective Assessment of Naps. In accordance with our continued emphasis on the need to study subjective fatigue in conjunction with traditional physiological and performance measures, we again included a number of rating scales which we have developed for assessing an individual's estimate of nap satisfaction, recovery from fatigue, and temporal characteristics of a nap period.

(1) Nap Satisfaction and Recovery from Fatigue. Subjects' satisfaction and recovery from fatigue following nap sessions (DAYS 2 and 3) are assessed by 11-point rating scales (range from -5 to +5) completed immediately after and again about an hour after the 60-minute nap periods (see Figure 6). We have found these post-nap measures to reveal some of the more dramatic differences between nappers and non-nappers.

(2) Temporal Characteristics of the Nap. Following a nap period, subjects are asked to estimate temporal characteristics of the nap such as: how long they slept, how long it took them to fall asleep, etc. These estimates can be directly compared to the actual physiological time of the nap -- for example, the sleep efficiency measures presented in this report -- for an assessment of agreement between these data domains.

5. Measurements Outside the Laboratory Sessions. Daily records of sleep patterns and circadian rhythms are recorded by subjects

at home, between laboratory visits.

(a) <u>Sleep Diary</u>. During the entire 30-day period covered by the four laboratory sessions, subjects will be asked to complete a 4-page sleep diary shortly after awakening each morning. This is the same diary we used in our previous napping studies. Its primary function is to provide a daily log of sleep/wake patterns, thus allowing us to evaluate the occurrence of naps in the larger sleep pattern.

(b) <u>Circadian Measures</u>. In order to assess the occurrence of naps within diurnal variations in physiology, arousal, and behavior, as well as potential napper - non-napper differences in circadian rhythms, we are attempting to have subjects collect 2-weeks-worth of data on their diurnal variations in oral temperature, subjective activation, and body motility. This occurs between laboratory sessions 3 and 4.

(1) <u>Oral Temperature</u>. Body temperature (oral, axillary, or rectal) is the easiest 24-hour biorhythm to measure - and therefore the most widely studied (Kleitman, 1963; Colquhoun, 1971). It follows a somewhat sinusoidal cycle, peaking in early evening and throughout early morning. We are having subjects record their oral temperature 5 times a day (after arising in the morning, around noon, 3:30 p.m., 7:30 p.m., and just before going to bed at night).

(2) <u>Subjective Activation</u>. Subjective ratings of arousal are known to show 24-hour cyclic variation similar to the body temperature curve with the exception of a post-prandial dip in arousal around 1 p.m. which is not seen in temperature (Colquhoun, 1971). We were pleased to find that the Thayer Activation-Deactivation Adjective Check List

(Thayer, 1967) has been reported to show consistent diurnal variations that correlate with measures of physiological activation (Clements, Hafer, & Vermillion, 1976). We are having subjects complete the short version of the scale each time they record their oral temperature.

(3) Body Activity. General activity levels are also known to display a 24-hour rhythm as a function of sleep/wakefulness cycles (Aschoff, Giedke, Poppel, & Wever, 1972). We hope to assess activity not only by way of an hourly activity log, but also through the use of an Actigraph which records activity over 15-minute epochs for a period of 64 hours. We are particularly eager to employ this technique because it offers a unique opportunity to validate the accuracy of sleep diaries and reports of napping patterns away from the laboratory. Self-report data of this kind permit the study of sleep and napping patterns over considerably longer periods than could feasibly be accomplished in any other way, but they suffer from the lack of objective verification. If independent checks on the accuracy are available, it becomes possible to determine which subjects' data are reliable and to use the findings with considerable certainty.

C. Current Work in Relation to Implementation of Prophylactic Napping

The concept of prophylactic napping continues to be the most promising approach to facilitate prolonged effective functioning in settings requiring quasi-continuous performance. Over the past year we have been encouraged by many instances of anecdotal reports which suggest that the spontaneous occurrence of prophylactic napping is

more common than we had recognized, at least for some people. Further, we have been impressed by the attention that is apparently paid to sleep discipline in the Chinese army.

Though logically persuasive, the argument for prophylactic napping needs solid empirical support before implementation can be considered. To this end it is essential to validate our early findings on napping types and to assess the effect of environmental circumstances on ease of napping for individuals showing different daytime sleep patterns. The evaluation of prophylactic napping which must inevitably take into account an individual's skill in utilizing daytime sleep even in environments hostile to sleep then becomes possible. Finally, if the utility of prophylactic napping to maintain effective performance over time is documented in the laboratory with replacement nappers, the extension of this research to field studies will become justified. At the same time it will also be necessary to develop and evaluate various techniques to train individuals who do not nap effectively to learn to nap at will, even when they are not tired, allowing them to obtain the benefits of prophylactic napping.

The study currently in progress is an extension of our early work on napping types and is assessing the effects of a sleep hostile environment. In the course of the study a group of individuals who can nap in anticipation of future sleep loss and in less than optimal surroundings will be identified. A laboratory study assessing the benefits of prophylactic napping to enhance performance will be carried out with a group of these individuals.

Thus, the work being conducted under the present contract should make significant progress toward the field application of pro-phylactic napping to prolong effective functioning under circumstances requiring quasi-continuous performance.

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SLEEP   ORAL TEMPERATURE
PERFORMANCE   CIRCADIAN RHYTHMS

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    The aim of our research has been to evaluate the potential of napping for facilitating quasi-continuous functioning. Earlier work by this laboratory has isolated individual napping patterns. Replacement nappers are individuals who utilize naps to make up for lost sleep or in anticipation of future sleep loss. Appetitive nappers nap even in the absence of fatigue because they enjoy the experience and derive psychological benefit from the nap. Non-nappers neither nap, nor do they find naps helpful. The current study expands these findings

20.

and explores the effect of asking individuals to nap in an environment not conducive to sleep. Further, it examines the effect of naps on performance. The overall thrust is to develop the concept of prophylactic napping as a means of training soldiers to utilize available slack time during quasi-continuous performance to prevent the accumulation of sleep debt, and thus maintain optimal functioning. In this report an updated review of the relevant literature on napping and fragmented sleep is included. Studies are discussed in relation to our approach to the use of napping. Further findings relevant to these issues are presented, including differences in sleep efficiency, delta sleep onset, oral temperature, and the factors that influence the ease of napping.

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